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HEREDITY, CORRELATION AND SEX DIFFERENCES IN SCHOOL ABILITIES

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HEREDITY, CORRELATION AND SEX DIFFERENCES IN SCHOOL ABILITIES

STUDIES FROM THE DEPARTMENT OF EDUCATIONAL PSYCHOLOGY AT TEACHERS COLLEGE, COLUMBIA UNIVERSITY

EDITED BY
EDWARD L. THORNDIKE

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INTRODUCTION.

THE extent to which hereditary relationships influence mental traits is a fact of prime importance to educational theory and practice. For all our educational endeavor is conditioned by the original natures of the individuals whose mental traits we attempt to change for the better. The relationships between mental traits in the same individual are also facts of no less importance to educational science than to theoretical psychology. For arguments for and against the existence and amount of disciplinary value of the different studies, schemes for groups of studies and the arrangement of curricula in general, rest in part upon opinions concerning the relationships of the abilities involved in the different school studies; and, finally, the nature of any ability or set of abilities will be defined as much by its relationships with others as by its own analysis.

Hereditary relationships and the correlations among mental abilities are therefore given a leading place in the list of topics for investigation by the department of educational psychology at Teachers College. The studies here reported are for the most part the work of candidates for the master's degree or diploma, who make psychology a minor and as a partial requirement collaborate with the instructor in the investigation of some simple topic.

In editing these studies I have cut out many of the explanations of procedure which, though they represent something important to the student, are dull reading to those more expert. I have also confined each paper to the dis-

cussion of the one main question it had in view. This implies the omission of a number of interesting results. I have further altered the text in the interest of uniform nomenclature and arrangement.

The work of collecting material, deriving results and drawing inferences was divided between student and instructor differently in different cases. Commonly both worked together throughout. My share in Mr. Burris' work, however, was only to furnish a part of the material and some help in the computation, and in Mr. Smith's only to advise and assist in the labor of computation.

EDWARD L. THORNDIKE.

Teachers College, Columbia University.

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THE RELATIONSHIPS BETWEEN THE ABILITIES INVOLVED IN THE STUDY OF THE GRAMMAR SCHOOL SUBJECTS.

BY A. G. SMITH, A. M.

THERE were two problems in view in this investigation. It was desired first to find what relationship exists between the mental functions involved in the pursuit of the different school subjects. In many schools a pupil's rating is based on his ability in one subject. If he is good for instance in mathematics, he is allowed to pass to a higher grade because his abilities in English, geography, etc., are thought to be dependent on or related to his ability in mathematics and similarly with other subjects in different places. In other words, ability—and I mean by ability, speed, accuracy and whatever helps to make goodness in anything,—ability in one subject or with one kind of data, is commonly supposed to mean ability also in some other subject or subjects. Is this true?

The second problem was: "What are the differences between boys and girls in this respect"? It may be that while two subjects are related in boys, they are not in girls; or it may be that there are no differences between boys and girls in this matter. Obviously it will greatly depend on the answer to this question whether our treatment of boys and girls in school is identical or different. The answer might also be of importance to so-called co-educational colleges, etc.

These then are the two problems. For evidence on the matter I attempted to obtain the records of one fourth

grammar class as it passed through to the first grammar. I found that by the time this class of fifty boys reached the first grammar grade, there were left but eight boys, all of different degrees of proficiency. Of the others, the majority had gone to work or to some other school, while the remainder were distributed through the intervening grades. This seemed to indicate that I had left, as a first grammar grade, a selected group of pupils and so with each lower grade. However if one fourth grammar grade sends about eight boys out of fifty straight through to the first grade, it is fair to assume that the three fourth grades do, too. Then we have accounted for about twenty-five or half of the first grade, there being only one first. If ten are those who were deficient last term, we have still fifteen to account for. They probably come from other schools and may be divided between those deficient in the first grade in some other school last term, and those selected for promotion from lower grades because they were brightest. Evidently while neither following a class through nor taking classes as they come is satisfactory, the latter is far more impartial as well as more practicable.

I obtained then the ratings given by eight teachers, one of boys and one of girls for each grade from the fourth to the highest inclusive, during five terms (two and a half years). These included the ratings of one thousand five hundred and twenty-nine pupils ranging from about thirteen years upward. In one grade only was there a change of teachers. The children were rated in English (composition and critical reading), in mathematics (arithmetic and simple algebra), in geography (physical and political), and in drawing (mechanical, ornamental, and artistic).

The marks which the teachers gave these pupils are reliable. In the first place my personal knowledge of the teachers, who are without exception successful teachers of

long experience, justifies confidence in their justice and accuracy. Then the system of marking, according to which these ratings are made, is prescribed for all: E, excellent, for those marks which in figures would be between ninety and one hundred per cent.; G, good, for marks between eighty and ninety; P, passable, for marks between seventy and eighty; U, unsatisfactory, for marks between sixty and seventy, and B, bad, for those below sixty; so that each pupil is given his proper relative place in the class. It is true that teachers' standards vary, but they vary in all ways, so that in a sufficient number of cases that will make no difference. Now it has been objected that teachers may have used these marks as a means of discipline. This is not true, for these are not monthly marks, to which the objection might hold, but the marks on which depended each pupil's promotion; and no teacher, certainly none of these, would give a pupil an irrational mark, if I may use the word in this sense, merely to punish him for misbehavior. Such an action not only would be distasteful and unprofessional to a good teacher, but is strictly and specifically prohibited by the by-laws of the Board of Education.

Further, in computing the averages preliminary to correlation, it is found that the ratings of the individuals of a class follow the normal distribution curves fairly well, that is, gravitate rather equally from above and below toward the class average. That is to say, if a class-average in English is G, roughly speaking about fifty per cent. of the class will have about G, twenty-five per cent. will have higher, and about the same per cent. lower marks. This is good evidence of the validity of the ratings.

The specific questions are:

How far does ability in English imply ability in geography?

How far does ability in English imply ability in mathematics?

How far does ability in English imply ability in drawing?

How far does ability in mathematics imply ability in geography?

How far does ability in mathematics imply ability in drawing?

How far does ability in geography imply ability in drawing?

The best measure of the relationships in the case of pairs of mental abilities is Pearson's co-efficient of correlation. To readers unfamiliar with statistical methods, I may explain that this is a figure so obtained that when the value is 0, it means that no matter how high or low a person's ability is in one of the pair of studies considered, he will in the other be indistinguishable from the general average; when its value is + 1.00, it means that a person of any degree of ability in the one will have precisely the same degree of ability in the other, and when its value is any fraction of + 1.00, it means that the possession of any degree of ability in one of the pair of studies implies the possession of that fractional part of that degree of ability in the other one of the pair. Thus, 0 correlation between English and arithmetic would mean that E's, G's, P's, V's, and B's in English would all do equally well in arithmetic. + 1.00 (or + 100 per cent.) correlation would mean that all the E's in English formed the highest group in arithmetic, that all the G's in English stood next highest in arithmetic, and so on, those getting B. in English being the lowest section in arithmetic. + 35.6 per cent. correlation (that actually obtained for boys in this case) means that if we take any group of boys in English who rank x. above or below the average, this group will, on the average, rank $\frac{35.6}{100}\,x$ above or below the average in arithmetic.

The Pearson co-efficients of correlation found are:

	Boys.	*Girls.*	*Average.*
English and mathematics	+ .36	+ .43	+ .395
English and geography	+ .49	+ .38	+ .435
English and drawing	+ .27	+ .14	+ .155
Mathematics and geography	+ .42	+ .30	+ .36
Mathematics and drawing	+ .16	+ .12	+ .14
Geography and drawing	+ .14	+ .11	+ .125

NOTE.—The method of calculating these co-efficients was by Pearson's formula, $r = \frac{\Sigma (x.y)}{n \sigma_1 \sigma_2}$, E, G, P, U, and B being assigned the values of + and — x and y in terms of the probable error as a unit, which they would have if the abilities in question were distributed according to the normal frequency curve. This is probably approximately the case. At all events, we shall probably be much nearer the truth to assume that E, G, P, U, and B compose a normal curve than to assume that E—G = G—P = P—U = U—B = a constant. Upon two assumptions, then, the correlation co-efficients measure the relationships between the abilities in question: 1st, that an E mark means better ability than a G, a G than a P, etc.; 2d, that the abilities themselves follow the normal type of distribution. The details of the calculation can readily be surmised by those acquainted with statistics, and would not interest others.

In addition to the school marks I used for correlation the abilities shown in certain examinations which were given to two fourth grades of boys and two of girls in arithmetic, grammar and geography. All four classes, about 200 pupils, took the same examination at precisely the same time, and each pupil was given sufficient time to complete the examination. The questions of the test were based upon the work which all had just finished for the month.

The papers were marked by the teachers and passed on by myself. A very rigid system of values was used in crediting the answers. Altogether the uniformity of the marks may be relied on.

As pertinent evidence to their validity, it will be noticed that here likewise the ratings follow roughly a normal distribution-scheme.

The Pearson co-efficients of correlation between arithmetic and geography examinations were obtained just as with the E G P V B marks. They are:

Grade A (boys)	+.26
Grade B (boys)	+.43
Grades A and B, together	+.34
Grade C (girls)	+.28
Grade D (girls)	+.45
Grades C and D, together	+.37
General average for boys and girls	+.355

The Pearson co-efficients were also obtained using the absolute marks as given, *i. e.*, on the basis that the step from the mark 95 to the mark 91 equals that from 67 to 63 or from 80 to 76.

By this method they are:

Grade A (boys)	+.23
Grade B (boys)	+.43
Grades A and B, together	+.33
Grade C (girls)	+.28
Grade D (girls)	+.57
Grades C and D, together	+.43
General average for boys and girls	+.38

It will be noted that the average of the two determinations (.355 and .38) is very close to that obtained from the term marks (.36).

The lack of any close relationships and the different degrees of correlation between different subjects are obvious. Such relationships as do appear may be due to various causes. It may be that these children are those selected by the school because they all approximate mentally a certain mind composition. I have mentioned above how the highest or first grade was composed of about 40 children, 10 of which were promoted regularly from each of the four fourth grades. That is, only about one-fourth were selected from the fourth for the first grade, the other three-quarters being eliminated until they do approach the standard set for them. This process of selection and elimination operates from the low-

est to the highest grades, as witness the general overcrowding of the lower grades and the abundance of primary schools as compared with the small number of grammar schools. This weeding-out by quite natural influences probably goes through high school and college too. Moreover, the school is constantly molding and warping the young mind toward the ideal which the school has before it, and ignoring or suppressing all faculties that are useless to this end. Therefore, that much of this correlation, which is very slight at all events, is due to a process of selection and suppression, and not to any relationship inherent in the subjects is quite probable.

Finally, let me point to the fact that there is a larger degree of correlation in these tables among boys than among girls. This raises the question as to the principles underlying the natural selection of boys and of girls. Has society one ideal for boys and another for girls? To this follows a long train of questions. They are at present the subject of an investigation.

THE CORRELATIONS OF THE ABILITIES INVOLVED IN SECONDARY SCHOOL WORK.

BY W. P. BURRIS, A. M.,

Principal of the Teachers' Training School, Albany, N. Y.

THE following account should be regarded merely as a preliminary report upon a rather extensive investigation which is far from complete. The baffling character of the problems with which it deals will be readily admitted and their importance likewise recognized.

The general problem with which the investigation deals is that of the relations of mental abilities found in pupils doing secondary school work. The problem is, of course, not a new one. It is one about which we can scarcely escape having opinions. Upon the basis of our opinions schemes of study are planned and in a variety of ways the work of secondary schools is shaped. But the vital character of the consequences involved renders it desirable that we get beyond mere opinion, if possible, and find something which we may take as fairly representing scientific truth. In other words, this investigation seeks, by the methods of science, to find a quantitative measure of relations between mental abilities in pupils who have reached what we call the secondary, or high school age. But let it be understood that we do not here offer anything which is capable of defense as being the exact measures which we seek. The most that we can promise, as yet, is a description of what seems defensible as a scientific method applied to problems

of this character and approximate results. So far as the actual results are concerned, we shall see that everything depends upon the reliability of the data with which the method deals; and, as we shall also see, there are numerous reasons for questioning the value of the data so far used. We shall point out, however, certain directions in which to look for what we hope may prove more reliable data from which to work out trustworthy conclusions.

Our general problem at once divides itself into two phases from the fact that the prevailing type of the American secondary school has pupils that are of the same parentage, and offers a variety of "courses" or "studies." More specific statements of the questions with which the research deals can best be made in connection with a word concerning the divisions of the investigation which are the outgrowth of the situation just mentioned.

1. *Hereditary Relations*. This is the first phase of the investigation with which the present account deals. We here seek to find a measure of heredity as a factor in education through a comparison of the school marks of pupils of the same parentage. All sorts of opinions prevail as to the extent to which mental ability is a matter of inheritance, from the one which holds that it is altogether a thing of inheritance (at least as much so as are physical traits) to the one which denies it altogether. Without doubt it is easy to offer numerous superficial arguments in favor of each of these views, and to cite what seem to be particular instances of the one or the other. Nevertheless, we must admit, for reasons which it is unnecessary to cite, that mental ability is to *some* extent an affair of heredity. The extent to which physical traits are due to inheritance has been quite accurately determined by Francis Galton and Karl Pearson, and there is little disposition to challenge their results, either on the part of scientific men or popular opinion. Can the

measure of mental inheritance be found in any similar manner? The difficulty of doing so may be readily admitted, but no one seems quite ready to say that it is impossible.

2. *Relations Between Abilities in Subjects.* There are several ways in which the work of secondary schools has become differentiated so as to give to the student, or his parent, a large measure of liberty in choosing studies. He may choose between schools, or between courses in the same school ("classical," "scientific," etc.), or between studies in the same school where there is a system of "electives" more or less elaborate. In a few centers one may find all of these types existing. But it would seem that the last named type is destined to become the dominant one,—at least in our country. Its wide-spread adoption is at least in part due to the assumption that mental abilities are specialized and grouped together in a variety of ways. Nor will any one be likely to question the essential soundness of this position. But what seems especially desirable, in order to choose most wisely, whether concerning schools, courses or studies, is some measure which will enable us to predict, at least with a high degree of probability, the studies for which individual pupils are best adapted. Moreover, in planning "courses," which are nothing more nor less than groups of studies, can it be done rationally except on the basis of the way in which certain mental abilities are found grouped in prevailing types of intelligence? Even in the organization of the private school one surely cannot justify what he offers merely on the ground of tradition, a spirit of exclusiveness, or the size of a purse. Nor can we justify a system of "electives" merely on the ground that it gives freedom. Unless a pupil choose in accordance with his capabilities, the elective system may even be a disadvantage.

What is the degree of probability that ability in science

carries with it ability in mathematics? Even in different branches of the same general subject, as algebra and geometry, what is the degree of certainty that ability in the one implies ability in the other? Is there a correlation between ability in Greek and ability in mathematics, and, if so, what is its extent? Does improvement in one involve improvement in the other, and can the extent to which training of one ability "spreads" to other abilities be measured? Is there a "blessed overflow" from the exercise of ability in Latin to ability in English, as is often contended? A pupil's ability in one or more subjects may be already known. On the basis of such knowledge can we predict to any extent his capabilities in other subjects? Can we measure general ability by special ability or special ability by general ability? In a word, can we measure the subjective situation so as to justify or modify the objective conditions? These and numerous other questions are involved in such an investigation as we have undertaken, and we offer here a brief description of a method of studying such questions and some provisional results.

The material thus far used in this part of the research consists of the marks of secondary school pupils in 16 different high schools located in the States of New York, Pennsylvania, Minnesota, and California. Persons in charge of these schools, except in one instance, kindly furnished the school marks of pupils of the same parentage. These marks had been given in different ways. In 6 schools records had been kept in the conventional per cent. system. In 9 of the schools records had been kept in as many different systems of arbitrary symbols, as A B C D E F, Pt Ex VG G Un P VP F, etc., and in the one school record to which I had access myself the record had been kept partly in letters and partly by showing a pupil's standing from quarter to quarter by means of a curve drawn from dot to dot in four spaces formed by five equi-distant parallel lines.

It was quite evident that before any use could be made of such marks in a common table of comparison, it would be necessary to transmute the records of divers pupils kept in divers ways by divers hands in divers subjects. Even in the six schools where grades were given in percentages on the basis of 100, it was readily seen that no two persons attached the same value to 70, 80, 90, etc. This was very clearly seen by the percentage of recurrence for each mark in the several schools, but more clearly still after the transmutation of these percentages into their common equivalents as described a little later.

Marks by these different systems can be made commensurate if we accept the hypotheses, (1) that the marks in any case give, subject to the error of the marker, the relative positions of the pupils within the group; (2) that the abilities in the school subjects follow the normal type of distribution, and (3) that high school students represent a random picking from the total group of boys and girls. We can then use the method adopted by Galton in the case of eye color, artistic tendencies, etc. (Natural Inheritance, Chapters VIII and IX), and from the fact that an individual is in such and such a percentage of the class (*e. g.*, the top 4 per cent. or the 13 per cent. beginning from the top 26 per cent. and running down), assign him a mark of such and such an amount above or below the average in terms of the variability of the group as a unit. The first hypothesis is true, the second is almost surely true, but the third is almost certainly false. For the high school almost certainly selects students above the average ability in scholarship more frequently than those below it, and probably eliminates altogether those far below it. This fact makes all our estimates of correlations inaccurate and *too low*. Just why will be clear to a reader versed in statistics and would even after a lengthy explanation remain obscure to one who was not.

By complicated treatment the material could be to some extent freed from this error, but not entirely. It seemed better to hold to a simple method of treatment and be satisfied with a result than which the true result will be greater.

It would have been safer to have made separate transmutations for boys and girls. For if there is a sex difference in ability the true measure for comparison would be any individual's superiority or inferiority *to the average for his sex*. The error due to mixing the sexes is, however, surely not great (for there is no striking sex difference in high school marks), and in the case of brother and sister comparisons would have a trifling influence.

We may take the English marks in one of the schools to illustrate the method of transmutation. The marks were A B C D E F. After scoring it was found that A as a mark in English in this school had been given 15 times, B 142, C 282, D 161, E 39, and F 2—total, 641. In other words, A had recurred about 2 per cent. of the times in which a mark had been given in this subject in this school, B 22 per cent., C 44 per cent., D 25 per cent., E 6 per cent., and F less than 1 per cent. With these percentages as a basis we took the highest 2 per cent. of Galton's table (Natural Inheritance, p. 205) and divided by 2 for the new value of A, which is 3.25. For the new value of B we added the twenty-two values for the next twenty-two per cents. and divided by 22, the result is 1.72. In a similar manner we found the average value of the next 44 per cent. (observing plus and minus signs) for the transmuted value of C. And so on with the other values. Having done this we substituted 3.25, 1.72, 0.02, –1.30, –2.56, and –3.45 for A B C D E and F, respectively, wherever they were found as marks in this subject in this school. If in a given year a pupil's English marks were, say BBCD, his grade for the year was the sum of the transmuted values of these letters divided by 4. As

a fact these letters did occur in all sorts of combinations and in this way pupils got grouped into a large number of classes, even though few letters were used in the system of marking.

What we have just indicated as the method of transmuting the English marks illustrates what was done for each subject in each school. It consists, in the first place, of finding the percentage of recurrence for each value given and then, on this basis, giving to the several marks a new value in terms of the Galton table. Where the school marks were given in the conventional percentages the number of times each percentage mark recurred was scored, and after the percentage of recurrence for each percentage mark was found we proceeded to find new values as in case of the letters illustrated above. In the case of the curves the method differed only in first substituting 1, 1.1, 1.2, etc., 2, 2.1, 2.2, etc., ... 4, for the curves, and then scoring up these substituted values, finding the percentage of recurrence for each, after which the procedure was the same as already indicated.

Having transmuted the marks in the different subjects in all of the schools, we proceeded to score comparisons of brother with brother, brother with sister, sister with brother, or sister with sister. In case of several children of the same parents we made as many comparisons as there were different pairs.

The degree of resemblance found in general in the case of the pairs thus related was measured by the Pearson co-efficient of correlation calculated by the formula r (the co-efficient of correlation) $= \frac{\text{Sum of all the x.y's}}{n, \sigma_1, \sigma_2}$. The co-efficients for the different subjects were as follows:

		Number of pairs.
English	+.24	550
Latin	+.24	400
Mathematics	+.20	554
History	+.16	450
Science	+.21	350
General scholarship	+.22	554

Could these resemblances have been due not to the similarity in ancestry, but to the similarity in home training of related children? One's answer to this question will inevitably depend upon his general view of mental heredity, based upon a survey of all the facts, which is here out of place. We may here note merely, in the first place, that high school pupils were selected for the research rather than elementary school pupils, largely for the reason that a pupil's success in high school is undoubtedly less influenced by the home than is his success in the elementary school. In the latter, parents help their children and children help each other, while in the former such environmental factors are unimportant. Moreover, if environment rather than heredity be the influence operating, it would seem, *a priori*, that there would be most resemblance in English and history. On the contrary, our results show the greatest agreement in a subject where there would seem to be the least possibility of home influence, viz., Latin. These are two good reasons, it seems to me, for saying that results obtained in this way may fairly be taken as a measure of heredity rather than environment.

There are, without doubt, several reasons for questioning the results which we have so far reached. The method which we have used presupposes the accurate measurement of the abilities which we have compared, and there are several chances for inaccuracy. (*a*) The personal equation which in a variety of obvious ways may influence school marks. (*b*) Different teachers in the same school do grade according to different standards. One may test for information and another for power, or one may think one power more important, while another may attach greater weight to some other power. The chances of error from this source could have been overcome, in a measure, if the marks of pupils graded by each teacher had been transmuted separ-

ately; but this could not easily be done, and teachers in most of the schools reporting change frequently, while the marks used in most cases were distributed over several years. (*c*) Different schools, as well as different teachers in the same school, have different standards, and while the chances of error from this source are largely eliminated by the transmutation of each school's marks separately, they could not be gotten rid of entirely. In some schools there were too few cases. In others, pupils fell into too few groups. In some the cases and the groups were both too few. These are some of the reasons for questioning the value of statistical comparisons based on school marks. That these influences had operated was clearly seen from the fact that the extent of correlation shown by the transmuted marks of some schools was far greater than in others.

4. The more important of these chances of error, we think, can be overcome. Such marks as those given by the Regents' Office, State of New York, ought to furnish data which would almost entirely remove the personal equation when such marks are treated, of course, according to the method which we have described. Moreover, this "ancient and honorable body" makes no radical change in standards, from year to year, and the work of a large number of high schools with fairly permanent faculties is practically shaped by this central examining body. Marks of brothers and sisters taken from their records ought therefore to furnish rich materials for such a study as this. Another way to correct our results would be to examine a sufficiently large number of high school pupils, placing before them such tests and using such a method as would be fair to all.

I have already attempted this, and the results of such examination are in my possession but have not been scored up. These results are probably too lacking in related individuals for the study of heredity, but doubtless will be of

value in the other phase of the general investigation. In these and other ways it ought to be possible to find light upon the many important questions involved.

For physical traits fraternal correlations vary between .40 and .60, and for certain mental traits Pearson obtains values within these same limits (Nature, Vol. 65, p. 118). The smallness of the co-efficients obtained in this study may therefore need a word of comment.

First of all we may repeat that the marks with which we started are probably far from being accurate measures of ability, and that no importance is attached here to the precise amounts of resemblance denoted by our co-efficients. It is risky to infer from the results of a study of approximate measures just what the outcome of exact measures would be. But they would raise rather than lower the co-efficients of fraternal correlation. Secondly, it has been already pointed out that these co-efficients are too small by an amount proportional to the extent to which high schools select the more scholarly of boys and girls without to an equal extent so selecting *within family groups.* In the third place, we ought to remember that fraternal resemblance measures inheritance when the related children "take after" the type midway between the two parents but not when they "take after" one or the other of the parents (exclusive, particulate or alternate inheritance).

This study may fairly be claimed to prove the existence of fraternal resemblance, to set at least a lower limit for it, to make it very probable that ancestry is the cause of at least a part of this resemblance.

The experience with the data presented by school marks emphasizes the desirability of paralleling this investigation by one with more uniform and objective marks.

The Relationships Between the Abilities in Subjects.

Using the same data we made a comparison of each pupil's ability in each subject with his ability in every other subject. The results are given in the table below. A coefficient of correlation here represents the relationship between two subjects in one series of individuals, not the relationship of the first and second members of pairs of individuals in the same subject.

	English.	Latin.	Mathematics.	History.	Geometry.
Latin	.48				
Mathematics	.39	.40			
History	.40	.43	.33		
Science	.41	.44	.41	.40	
Algebra	—	—	—	—	.45

We also compared each pupil's ability in each subject with his ability in general, as represented by his general average in all studies, with a view to finding what subject may most likely represent or be a measure of his general ability. These results are as follows:

	English.	Latin.	Mathematics.	History.	Science.
General Average	.54	.57	.53	.49	.57

The mixture of the sexes would in these cases result in making all the coefficients higher than they really are in proportion to the difference between the sexes in the two traits, *provided the same sex was superior in both the subjects compared.* The opposite effect would be produced if the sex superior in the one were inferior in the other.

The effect of the selection by the high schools of superior

students would be to make all the coefficients here given represent values lower than the real values. Unfortunately we have no accurate means of deciding how much lower.

The error of teachers in marking would probably be to deviate from any student's real ability in a subject toward his ability in some other subject, for the teacher would be influenced by the student's previous record, ability in other classes taught by that teacher or his associates, and his fidelity and personal attitude, matters likely to be common to all his school work. Taking all these matters into consideration, the real relationships are probably approximately given.

Their small amount shows the specialization of the different studies and branches of the same study; their relative amounts show the absence of any especial grouping of school abilities, and suggest that an adequate study of school abilities would make our common talk about the grouping of subjects ridiculous.

My thanks are due to the following persons for a large part of the data upon which this study is based:

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THE RELATIONSHIPS BETWEEN THE ABILITIES INVOLVED IN SECONDARY SCHOOL SUBJECTS.

BY EMILY C. BRINCKERHOFF, B. S., GEORGE MORRIS, A. M., AND EDWARD L. THORNDIKE.

It is by no means certain that high school marks measure school abilities other than the ability to get such and such a mark. In particular any teacher would seem almost sure to be influenced by a pupil's looks, general manner and mental attitude. But these might be identical no matter what the subject was or the pupil's real ability in it. It is very difficult to get adequate objective records from high school pupils and very laborious to assign marks on the basis of such records. Mr. Burris has obtained some material of this sort and is at work upon it. The present study is based upon measures of ability that are midway between the mere school marks and purely objective marks.

In the fall of 1900 Miss Brinckerhoff suggested the use of the marks given in the New York Regents Examinations, and obtained the records in from 8 to 30 examinations each of 232 boys and girls. The difficulty with this material she found to be that cases of failure in the examination were not always reported, and cases where a pupil avoided the examination because of his obvious inability in the field are not reported at all. The advantage lay in the fact of the uniform grading by a large number of pupils and in the fact that the individuals all came from one school, so that their ability, not their training, was measured. College entrance examination marks, for instance, fail to meet the latter desi-

deratum. Miss Brinckerhoff and Mr. Morris shared the labor of plotting correlation tables, and estimating the amount of correlation by a rough calculation of Galton's function. Later I calculated the Pearson co-efficients for the highest 50 per cent. in each study with the other studies in those cases where the number of individuals was sufficient to make this worth while. By thus taking only the upper half we to a large extent eliminate the inaccuracy due to the absence of cases of total failure. The co-efficients so obtained are given in Table I. It would have been better to treat the sexes separately, but at the beginning of the work this was not realized. The differences between the sexes in the degree and variability of ability are slight, so that the mixture does not produce any considerable amount of spurious correlation. The measure used for any individual in determining the co-efficients was the difference of his mark from the median mark of the whole group. His mark equalled the average of all his examination marks in the subject in question. In the case of the science marks all the separate science marks except physiology (which is an extremely perfunctory study in the school whence these data came) were averaged.

TABLE NO. I

	Latin.	English.	Mathematics.	Science.	History.	German.
Latin						
English	.50 *70*					
Mathematics	.31 *66*	.09 *104*				
Science	.35 *34*	.26 *88*	.07 *75*			
History	.44 *57*	.41 *100*	.26 *108*	.61 *55*		
German	.48 *31*	.30 *60*	.48 *51*	.57 *36*	.42 *49*	
Drawing	.40 *55*	.20 *80*	.02 *85*	.30 *59*	.16 *87*	

The figures in italics give the number of cases from which the coefficient was calculated. From them the reliability of the coefficients can be calculated.

If we compare these co-efficients from regents' examination marks with those from teachers' marks obtained by Mr. Burris, we get the following list (the regents' co-efficients are in italics):

	English.		Latin.		Mathematics.		History.	
Latin	.48	*.50*						
Mathematics	.39	*.09*	.40	*.31*				
History	.40	*.41*	.43	*.44*	.33	*.26*		
Science	.41	*.26*	.44	*.35*	.41	*.07*	.40	*61*

THE RELATIONSHIPS BETWEEN THE DIFFERENT ABILITIES INVOLVED IN THE STUDY OF ARITHMETIC. SEX DIFFERENCES IN ARITHMETICAL ABILITY.

BY W. A. FOX, SUPT. OF SCHOOLS, ALBION, INDIANA, AND EDWARD L. THORNDIKE.

THE following tests were given to 77 students in a high school (28 boys and 49 girls). These students were distribnted as regards age as follows:

Age	14	15	16	17	18	19	20
Number of cases—							
Boys	1	3	5	9	7	2	1
Girls	4	8	16	14	5	2	0

ADDITION EXAMPLES (1)

(Given 5 times)

17	26	27	72	23
42	52	24	14	47
38	47	83	39	86
91	82	19	81	54
54	63	45	26	36

17	42	38	91	36
26	51	47	82	26
27	24	83	19	45
72	14	39	62	63
23	47	86	54	54

41	53	67	78	86
52	67	86	37	32
86	34	23	96	44
23	78	45	72	36
35	19	67	23	68

45	52	19	45	23
13	86	78	67	72
68	23	67	78	36
77	35	23	37	68
86	67	86	96	39

Multiplication Examples (1)

(Given 5 times)

7986	7869	9867
4523	5324	3425
8679	7968	7698
3542	3254	5423
8967	7896	6493
4532	5243	8786

Multiplication Examples (2)

(Given 5 times)

9468	5426	3795
3752	9378	2684
4932	8376	7264
5764	4952	8539
2869	6492	9425
7453	5763	6387

Fractions (1).

1. How much is $\frac{7}{5} + \frac{3}{4} - \frac{5}{8} + \frac{2}{3} - \frac{7}{6}$?
2. How much is $\frac{96}{45} \times \frac{22}{13} \times \frac{52}{16} \times \frac{18}{44}$?
3. How much is $\frac{81}{42} \times \frac{14}{27} \div \frac{65}{9} \times \frac{7}{26}$?
4. To $\frac{9}{4}$ add $\frac{3}{7}$; divide by $\frac{16}{56}$; add $\frac{12\frac{1}{2}}{8}$; multiply by $\frac{4}{5}$.

Fractions (2).

1. How much is $\frac{3}{8} + \frac{4}{7} + \frac{6}{14} - \frac{11}{28}$?
2. How much is $\frac{108}{39} \times \frac{6}{8} \times \frac{2}{3} \times \frac{13}{3}$?
3. How much is $17\frac{7}{9} \div 1\frac{8}{28}$?
4. To $\frac{3}{8}$ add $\frac{2}{3}$; divide by $\frac{5}{16}$; add $\frac{2}{3}$; multiply by $\frac{1}{2}$.

Rational Computation.

1. How much is $\frac{144}{9} \times \frac{27}{12} \times \frac{2}{9} \times \frac{27}{21}$?
2. How much is $5\frac{3}{8} + 1\frac{1}{4} + 6\frac{1}{2} - 7\frac{1}{8}$?
3. If a girl had two dollars, three five-cent pieces, two dimes and three quarter-dollars, how much money would she have in all?
4. How much is $\frac{48}{12} \times \frac{14}{7} \div \frac{36}{18} \times \frac{27}{9}$?
5. To 92 add 8; divide by 32; multiply by 8; subtract 5; multiply by 39; divide by 13.
6. How much is $\frac{39}{5} \times \frac{2}{5} \times \frac{15}{26} \times \frac{4}{9}$?
7. How much is $37\frac{1}{2} + 87\frac{1}{2} + \frac{250}{4} + \frac{1}{2} + 6$?

Problems—Test A.

1. If a boy has 144 nuts and gives his brother three-eighths of them, his sister half as many as to his brother, and to a friend a third as many as to his sister, how many nuts will the boy have left?

2. Four men arranged to build a wall. They were to receive in all 192 dollars. One man got 48 dollars, another 16 dollars, another 80 dollars, and another what was left. The wall was 288 feet long. How much of it ought each man to build?

3. A man sold 72 barrels of apples at $2.75 per barrel and bought with the money from the sale some cows at $16.50 apiece. How many did he buy?

4. A peddler wished to swop handkerchiefs at $12\frac{1}{2}$ cents apiece for chickens at 37 cents. How many chickens must he take in order to have a perfectly even swop?

Problems—Test B.

1. A man left 2,200 dollars to be divided as follows: Half to his son, one-fourth to his daughter, one-eighth to his brother, and the rest to St. Luke's Hospital. How much did the hospital receive?

2. A freight train left Albany for New York at 6 o'clock. It went at the rate of 24 miles an hour. An express left on the same track at 8 o'clock. It went at the rate of 40 miles an hour. At what time of day will the express train overtake the freight train if the freight train stops after it has gone 56 miles.

3. If eight men can do a piece of work in 12 days, and if a boy can do two-thirds as much work as a man, how long will it take six boys to do the work?

4. A man spent one-eighth of a certain sum of money for horses and three times as much for cows. Half of what he had left was $800. How much interest would he have gotten in a year from the whole sum at 4 per cent.?

All the tests were given by the same individual, each test

being given always in the same manner. A fixed amount of time was given for each test, short enough to prevent even the best student from finishing.

All the papers in addition and multiplication were marked by objective criteria, that is, a fixed rule of scoring was adhered to in all the papers for each test. This was in addition, the number of half examples done minus the number of errors made; in multiplication the number of sixths of an example done (each partial product counting one-sixth and the subsequent addition counting two-sixths) minus the number of errors made. The papers in fractions, rational computation and problems, were marked in each case all at one sitting, and with the intention of having any one unit o the mark equal to any other unit. The variety in errors made any single objective scheme of marking too cumbersome.

We have thus for each individual a record of ability in these several tests, in addition and multiplication a very accurate record. (The marks in multiplication have a probable error surely less than 4 per cent. of their amount; those in addition a probable error surely less than 3½ per cent. of their amount.) By calculating the Pearson coefficients of correlation we obtain measures of the closeness of the relationships between these different abilities. The relationships thus measured will of course be those due to the differences in maturity and school training that characterize a high school population as well as to the intrinsic connection between the psychological functions involved. The influence of sex was eliminated by working out coefficients for the sexes separately.

The elimination of the influence of differences in maturity and differences in school training would mean the testing of at least five hundred students. This study will at least give a limit which the necessary or intrinsic relationship will not

exceed. As the contention of this paper will be that the different abilities involved in the study of arithmetic are decidedly unrelated, independent, specialized, the coefficients here obtained will be unfair only against this contention. What they show would be shown *a fortiori* by the coefficients measuring the necessary relationships.

The coefficients calculated and their errors of mean square Note) are as follows:

1. Addition with Multiplication	.75	.05
2. Addition with Fractions 2	.44	.12
3. Addition with Fractions 1	.19	.19
4. Addition and Multiplication combined with Fractions 1 and 2 combined	.46	.c9
5. Addition and Multiplication combined with Problems A and B combined	.55	.08
6. Fractions 1 and 2 combined with Problems A and B combined.	.44	.12
7. Addition and Multiplication combined with Fractions 1 and 2 and Problems A and B all four combined	.54	.08
8. Fractions 1 with Fractions 2	.20	.17
9. Fractions 1 with Rational Computation	.58	.10
10. Fractions 2 with Rational Computation	.57	.09

NOTE.—This figure gives a measure of the unreliability of the co efficient due to the small number of cases studied. Thus the first line should read, "A relationship of 75 per cent. and the chances are 2 to 1 that if an infinite number of cases had been studied the co-efficient then found would not vary from .75 by more than .05, would be that is between .70 and .80."

The first three co-efficients show clearly that different degrees of kinship exist between different arithmetical abilities. The next three emphasize the mutual independence of the abilities involved in semi-automatic computation, the more difficult computation of fractions, and in solving problems. To one used to common speculations about arithmetic it may seem strange that the last is no more closely allied to the second than to the first. If doing problems involves primarily arithmetical analysis and reasoning, skill in it would be much more closely allied to skill in the working of

fractions than to the mere associative processes involved in adding and multiplying. The fact is that neither in problems nor in fractions (nor for that matter anywhere else) do the vast majority of scholars use arithmetical analysis or reasoning. Out of forty adults (all school teachers and many of them college graduates) only two showed any conception of the logical methods of attack in tests with Problems A and Rational Computation. The seventh correlation is given to show that the smallness of the others is only slightly changed by getting more extensive information concerning ability in the harder tests, as we do by getting each single mark from four tests instead of two. Correlations 8, 9 and 10, show further that the common notions concerning the reasoning used in arithmetic are purely speculative. The Rational Computation test correlates as well with Fractions 2 as with Fractions 1, though the former is much easier and gives much less opportunity for arithmetical insight.

The small amounts of all of the relationships demonstrate that the real abilities involved in the study of arithmetic are many, and are largely independent of one another. The relationships are in general not very much larger than those between different high school subjects. Just what is the psychological constitution of each of the separate abilities that together make up the composite "arithmetical ability," direct study will in time ascertain. We venture to prophesy that these abilities in boys and girls at school bear little resemblance to those of the mathematician, and still less to those of "the child" as imagined by books on methods of teaching.

In any comparison of the sexes it is of prime importance to make sure that the individuals studied represent an impartial selection in both cases, or at least are selected in identical ways. Of this we cannot be sure in the present

study. There is some reason to believe that the brighter boys in the town where these tests were given go to work frequently after graduation from the grammar school, and that consequently the high school has unfairly large proportions of mediocre boys and bright girls. The amount of this eliminating agency cannot be determined from our data. We give the figures for the cases at hand, with the warning that here (and elsewhere) tests of the two sexes are likely to be tests of groups picked for differing traits.

Arithmetical Abilities of the Sexes Compared

High School Students. Number of Cases: Boys, 16 to 25; Girls, 26 to 47

	Median Ability.		Average Ability.		Approximate Probable Errors of Medians and Averages.	
	Boys.	Girls.	Boys.	Girls.	Boys.	Girls.
Addition	17.0	17.1	19.4	17.8	1.0	0.6
Multiplication	23.0	23.9	22.1	24.2	1.2	0.7
Fractions 1	8.0	9.4	8.0	8.5	0.6	0.6
Fractions 2	10.2	11.2	9.0	11.0	0.9	0.7
Rational Computation	18.5	17.3	18.8	19.0	1.0	0.8
Problems A	8.0	9.6	8.3	9.2	0.4	0.3
Problems B	5.7	60.	7.0	6.5	0.6	0.3

Not much more can be reliably inferred from these figures than that the class of girls represented in this high school do about 5 per cent. better on the whole than the class of boys represented in the same school. The separate comparisons would have too wide a limit of error to allow inference.

The average or median abilities of the sexes might, in any case, be the same and still the variabilities of the two groups might differ widely. It is a common opinion that males vary much more; that in any line the best man is much better than the best woman and the worst man much inferior

to the worst woman. Our records give upon this question the following information:

The co-efficients of variability (average of the deviations of all the individuals from the average for their sex divided by that average) for girls are, on the average, 92 per cent. as large as those for boys. The probable error of this 92 is 5. The figures are:

CO-EFFICIENTS OF VARIABILITY.

	Boys.	*Girls.*	*Ratio.*
Addition	30	19	.63
Multiplication	24	21	.88
Fractions 1	39	47	1.21
Fractions 2	43	38	.89
Rational computation	32	38	1.19
Problems, A	30	26	.87
Problems, B	49	37	.75

Any individual is characterized not only by his average ability in any mental operation, but also by the constancy of his performance. In ten tests in any school subject A and B may both attain an average of say 8, but be of very different make-up and require very different teaching if their average deviations from the average 8 are respectively 4 and 1. In such a case A would need training in steadiness and could probably eventually reach a higher average attainment than B.

It is, therefore, important to compare the sexes with respect to the variability of performance of individuals. Our records give an opportunity for such comparison in the case of addition and multiplication. The proper statistical method is to get for each individual his average deviation from his average, divide it by the average to get the co-efficient of variability of performance for that individual, and then compare boys and girls with respect to the averages or medians of these co-efficients. We have somewhat shortened the

process by averaging the average deviations for individual boys, dividing by the average ability of all boys in the group, doing the same for girls, and comparing the quotients. The results are that in addition the girls are 93 per cent. as variable as the boys and in multiplication 96 per cent. as variable.

These sex differences are notable chiefly for their small amount. So far as our data go, there is no reason for any sex differentiation in arithmetical training.

THE INHERITANCE OF THE ABILITY TO LEARN TO SPELL.

BY E. L. EARLE, PH.D.

[IN an examination of a few pairs of brothers and sisters undertaken at my advice in 1900, Mr. L. W. Cole, Instructor in Psychology at the University of Oklahoma, found marked resemblances in spelling ability. I found the same to be the case with another small group from a different school. Mr. E. L. Earle then undertook to measure the resemblance in a large number of cases. His material was obtained from two school systems.

Of course the best way to compare related children is to use measurements taken with the same test under identical conditions of training. This however forces one to use adults as subjects (and experience shows that records of adult brothers and sisters are very hard to obtain) or to give tests in the same grade year after year. Only if a person's relative ability compared with those of equal training remains unchanged as training increases, can we compare a child with a brother in a different school grade. This may be the case. Just as the cephalic index remains unchanged after two years in spite of the growth of the skull, so one's relative ability to spell may not alter.

At all events Mr. Earle's results show very marked fraternal resemblance. This might be increased but could hardly be decreased in the case of a less hypothetical method. In a few years I shall have material from adults and from related children tested when in the same grade.

Limits of space prevent the insertion of more than a skeleton of Mr. Earle's report of his work. E. L. T.]

The tests used to measure spelling ability were:

1. P test. Parliament, reluctance, independent, engagement, interruption, necessary, judgment, acknowledged, development, stationery, manoeuvre, refinement, permission, possess, restaurant, familiarity, vitiate, committee, millinery, parallel, occurrence, criticise, column, disease, suffocation.

2. G test. Grateful, elegant, present, patience, succeed, severe, accident, sometimes, sensible, business, answer, sweeping, properly, improvement, fatiguing, anxious, appreciate, assure, imagine, peculiar, character, guarantee, approval, intelligent, experience, delicious, realize, importance, occasion, exceptions, thoroughly, conscientious, therefore, ascending, praise, wholesome, prevalent, difference, triumph, pleasure.

3. R test. Running, slipped, listened, queer, speech, believe, weather, changeable, whistling, frightened, always, changing, chain, loose, baking, piece, receive, laughter, distance, choose, strange, picture, because, thought, purpose, learn, lose, almanac, neighbor, writing, language, careful, enough, necessary, waiting, disappoint, often, covered, mixture, getting, better, feather, light, deceive, driving, surface, rough, smooth, hopping, certainly.

4. B test. Boy, milk, with, face, name, water, supper, long, horse, story, word, school, lady, snow, garden, girl, little, white, black, pretty, large, small, half, hungry, afraid, chair, meat, busy, lesson, throw, down, boat, wood, mouse, dress, sister, bread, happy, give, sweet.

In every case the measure used was the percentage of words correct. The tests were in each school all given by the same individual in the same way. The mark assigned to any individual brother or sister was his distance above (plus mark) or below (minus mark) the average for his

grade and sex in terms of the average deviation of that grade and sex as a unit. All the marks are thus comparable within one school, except for the fact that higher grades are selected groups of children. This is unfortunately a very important factor in School A, and makes the results from its records unreliable. School B is fairly free from it. Table I gives all the facts from which individual measures were calculated.

Fraternal resemblance is then calculated for each school by obtaining the Pearson coefficient of correlation for brother-brother, sister-sister, and brother-sister relationships. These coefficients are:

School A.	BB resemblance	.22	n = 45
	SS "	.32	n = 62
	BS "	.22	n = 84
	General fraternal resemblance	.25	n = 191
School B.	BB resemblance	.56	n = 48
	SS "	.48	n = 44
	BS "	.50	n = 104
	General fraternal resemblance	.51	n = 196

These figures mean that any degree of goodness or badness in spelling in one member of a pair implies on the average, .22 or .32, or .56 (or whatever the per cent. is), as much goodness or badness respectively in the other member of the pair. That is, if we take the figures for School B, $\frac{2}{1}$, the brothers of boys 10 above the average will on the whole be 5.6 above, the brothers of those 8 below the average will on the whole be 4.48 below, etc., etc.

The results from School B are far more reliable than those from School A, for B is a private parochial school attended continuously by the children of certain families. For all its children the school environment has been nearly the same. The children in the higher grades represent fairly well what the children in the lower grades will be. School A, on the

contrary, is a public school system. Consequently, children of the same family must have had different training in spelling in all the cases where the family has recently moved to the town. Different teachers of the same grade are more likely to use different methods than in School B. As the tables show, the children of the higher grades are a very small selection of those in the lower, and so comparison with the average of one of these grades is farther from being identical with the same process in a lower grade than it is in School B.

The results from both schools are to some extent inaccurate, in that the four tests used are not necessarily all tests of just the same ability; the distribution only roughly approximates to normal, and so the average need not be the point from which to measure ability, nor the average deviation be the right unit to measure it in; the higher grades never represent quite the same groups as the lower.

The results are, however, amply sufficient to demonstrate fraternal resemblance, and in so far as this resemblance cannot be accounted for by similarities in home training, to demonstrate inheritance of the ability to learn to spell.

TABLE I.—SCHOOL A

Showing Tests Used, Number of Cases and Distribution of Ability in each Grade. 4–8 are Grammar School Classes, 9–12 High School. Opposite each Degree of Ability is the Number of Cases in each Grade that Possess it. In the case of Grades 6 and 7 and Grammar 2 in School B, final figures 2 and 8 equal 2.5 and 7.5, and final figure 4 equals 5.

Grade	4		5		6		7		8		9		10		11		12	
No. of boys	101		71		46		31		21		12		21		8		8	
No. of girls	87		70		61		39		44		27		21		12		8	
Test used	R.		R.		G.		G.		P.		P.		P.		P.		P.	
	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.
8 % correct		1																
10 " "			1															
12 " "			1															
14 " "																		
16 " "																		
18 " "			1															
20 " "	1				1				1								1	
22 " "																		
24 " "							1											
26 " "																		
28 " "						2												
30 " "			2		1	2												
32 " "					1	2	1			2			1					
34 " "	2																	
36 " "	2	1								1	1	1	1					
38 " "		1		1	2													
40 " "	5	3	1				1					3	1					
42 " "	1	1	1		5	5												
44 " "	4	1	1		1	3	1	2	3	1	1	1	3					
46 " "	3																	
48 " "	2	4	3		2	1		1	3				2	1				
50 " "	7	3	2		2	4	3											
52 " "	3	1	1		1	2			1	6		2						
54 " "	5	4	2		1	6												
56 " "	4	4							1	6		1	3	2		2	2	
58 " "	1	2	1	2	3		1	1										
60 " "		2	1	1	1	1	1	1	3	5	4	2	2	2	2	6	1	1
62 " "	6	4	4			2	1	2										
64 " "	7	5	2	3	2	4	3	2	3	5		7	3	2	1			2
66 " "	5		1	1														
68 " "	7	2	2	2	3	1	1	1	2	4	1	1	2	4	1	1	1	
70 " "	4	6	2	4	1	4		5										
72 " "	1	3	6	4	1	4	2	1	2	4	3	4			3	1	1	
74 " "	3	4	6	3	3	5	2	2										
76 " "	4	4	6	4					2	6		2	1	2	1	1		2
78 " "	5	6	1	4	4	4	3	3										
80 " "	5	5	3	14	4	2	4	4		2			1	3		1		
82 " "	2	7	1	2	3	1		3										
84 " "	5	3	6	8	1	3	5	3		2	1	2	1	3				1
86 " "	2	1	5	4														
88 " "	2	4	2	5	1	2		3				1		1			1	2
90 " "	1	3	2	3	1			1										
92 " "			1	1	1		1	3			1			1				
94 " "	1	2	2	1				1										
96 " "	1		1	1													1	
98 " "				1														
100 " "				1		1												

TABLE I. (*Continued*)—SCHOOL B.

	PRIMARY.						GRAMMAR.							
Grade	3		2		1		4		3		2		1	
No. of boys	28		41		42		47		54		47		44	
No. of girls	15		31		39		53		56		53		28	
Test used	B.		B.		B.		R.		R.		G		P.	
	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.
8 % correct													1	
10 “ “									1					
12 “ “											1		1	
14 “ “									2		2			
16 “ “									2				2	
18 “ “		2									1			
20 “ “			2								2		2	
22 “ “		1												
24 “ “	2		2						1		1	1	2	
26 “ “														
28 “ “	1		3						1				1	
30 “ “	1							1	1		2			
32 “ “			5	1			1				1	1	1	
34 “ “											2			
36 “ “			3	1			3	1	1				1	
38 “ “	1						1					1		
40 “ “	2	1	5	2	3		3		1	1	1		1	1
42 “ “							3	2			1	1		
44 “ “	1		2	3	3						1		2	
46 “ “	1						1	3	1					
48 “ “	1	1	2	5	2	1		2			1	2		
50 “ “	4	1					4		1		2			
52 “ “	1	1	5	2	3	2	1				1	2	4	
54 “ “							1		1	1	5	2		
56 “ “			2	3	2	1	2	2	2	1			5	
58 “ “							2	2	1		1	1		
60 “ “	2		5	5	3	3	3	3	2		2	1	3	
62 “ “							3	5	2		3	1		
64 “ “	1	1	3	3	3	5	1	3	1	2	3	6	4	4
66 “ “		3					3	2	3	2				
68 “ “	1		2	3	5	3	2	2	1	1	3	6	4	1
70 “ “	1	1					1	5	4			1		
72 “ “	1			1	3	5	2	2	3	1	2	2	4	4
74 “ “	2	1					2		2	2	3	5		
76 “ “				1	4	5	3	2	1	1			2	1
78 “ “	1							3	2	5	1	3		
80 “ “	2	1		1	2	5				5	1	1	1	3
82 “ “	1	1					3	4	3	4		4		
84 “ “	1				4	3		2	4	8	1	4	2	6
86 “ “									3	5				
88 “ “					5	1		5	3	7		3	1	3
90 “ “							1		1	6		4		
92 “ “						5	1		1	1	1	1		3
94 “ “									1		1	1		
96 “ “								2	1	2				1
98 “ “										1	1			
100 “ “														1

A SEX DIFFERENCE IN SPELLING ABILITY.

BY E. L. EARLE AND EDWARD L. THORNDIKE.

OBSERVANT teachers are aware that girls are better spellers than boys in cases where the training has been the same, but there have not been to our knowledge any accurate determinations of the extent of this superiority. We have obtained fairly adequate measures of spelling ability from about 1600 boys and girls, representing three different school systems. The tests given were, in any case, one or more of the four sets of words on page 42.

We may compare boys and girls most accurately and completely by using in each case the actual distribution of the ability. Thus, in figure 1 we see the entire record for 2d grammar grade boys in school B compared with the entire record for 2d grade girls in the same school. But such a comparison, involving over a score of pairs of distribution curves, is tedious and so complicated as to obscure the general result. In this article, therefore, the method of comparison will be as follows:

Find the median ability for the girls in a class (*i. e.*, the ability reached or exceeded by 50 per cent. of the girls). Then find what per cent. of boys in the class reach or exceed that ability. The difference in per cents. measures the difference in ability. For instance, in the case pictured in Fig. 1 only 22 per cent. of boys reach or exceed the ability reached or exceeded by 50 per cent. of girls. This way of measuring the relative abilities of any two classes is much superior to a mere comparison of the two averages for the

two classes, for by it the terms of comparison are identica no matter what the test. For instance, with a set of eas words the average might be, girls 90 per cent. correct, boy 85 per cent. correct, while for a hard set given the same clas the average might be, girls 30 per cent. correct, boys 20 pe cent. By the averages alone we should have to say that i Test 1 the girls did about 6 per cent. more than boys, an in Test 2 50 per cent. more, while if we took the percentag of boys doing as well as a certain percentage of girls, w

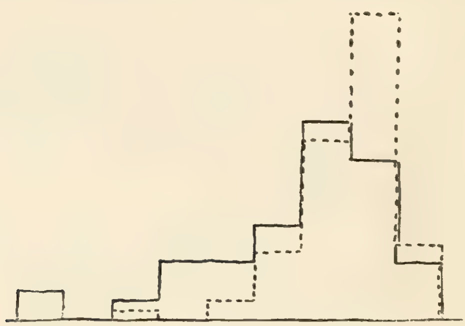


FIG. 1.

should find it almost identical in the two cases. Any othe investigator may thus use any tests he finds desirable an still, if he measures sex difference by the method used here compare his results with that obtained here.

The result is, that on the average only 33 per cent. o boys reach or exceed the spelling ability reached or exceeded by 50 per cent. of girls of the same amount o training.

This single figure is obtained as follows: In each class o each school boys and girls are compared in each test give by the method just described. The number of cases of the smaller group, whichever it may be, is noted. We have thus a set of facts like these: In School A, grade D, with the "parliament" test, on the basis of 21 cases, we find girls 5c

per cent., boys 14 per cent.; with the "grateful" test, on the basis of 21 cases, we find girls 50 per cent., boys 12.5 per cent. The average for both tests is, boys 13.25 per cent. In School A, grade 9, "parliament" test, on the basis of 31 cases, we find boys 37 per cent.; with the "grateful" test, 31 cases, we find boys 26 per cent. The average for both tests is 31.5 per cent. Take the average for each grade, multiply it by the number of cases, add all such products for all the grades together, and divide by the total number of cases.

The results by school grades and tests from which the 33 per cent. general average was obtained are given in Table 1.

Concerning this sex difference, it may be said that it cannot be explained by the earlier maturity of girls, for in a majority of mental and motor tests boys of the same age as girls surpass them. It does seem to be one feature of a general superiority of girls in tests involving the perceptive powers (success in spelling is largely due to ability to perceive and attend to the formation of words). Such are tests in marking out words containing certain letters or tests of memory-span, and in these also we find girls to be superior.

TABLE I.

In each school the grades are put in order, the highest coming first. P = *parliament* test, G = *grateful* test, R = *running* test, B = *boy* test.

School A.

Grade.	Number of cases of smaller group used in the comparison.	Test.	Per cent. of boys.	Test.	Per cent. of boys.	Average per cent. of boys.
12 (4th year high school)	8	P	25	G	......	12.5
11	8	P	62.7	G	......	61.8
10	21	P	14	G	......	13.3
9	16	P	50	G	......	47.5
8	21	......	......	G	43	43
7	31	G	37	R	26	31.5
6	49	G	54	R	49	51.5
5	70	G	34	R	33	33.5
4	86	......	......	R	33	33
Whole School	310	......	......	......	......	36

School B.

Grade.	Number of cases of smaller group used in the comparison.	Test.	Per cent. of boys.	Test.	Per cent. of boys.	Average per cent. of boys.
1 (highest grammar)	30	P	7	G	18	17.5
2	47	G	22	R	18	20
3	54	......	......	R	24	24
4	59	......	......	R	31	31
1 (highest primary)	38	R	31	B	36	33.5
2	39	R	33	B	27	30
3	15	......	......	B	36	36
Grammar Grades	180	......	......	......	......	23
Primary Grades	92	......	......	......	......	32

School C.

Grade.	Number of cases of smaller group used in the comparison.	Test.	Per cent. of boys.	Test.	Per cent. of boys.	Average per cent. of boys.
8 (highest grammar)	51	......	......	P	46	46
7	36	......	......	P	33	33
Whole School	87	......	......	......	......	41
Total	669	......	......	......	......	33

AN INDUCTIVE STUDY OF THE ABILITIES INVOLVED IN DRAWING.

BY ABRAM FISCHLOVITZ, A. M.

THE aim of this study was to discover what relationship exists between ability in drawing as measured by the opinion of the teacher and mere motor ability of the hand as measured by quickness and accuracy determined by means of the following test: To draw a line between the lines of Figure 1 and within the path of Figure 2 without touching the lines on either side. In so far as the opinion of the teacher is a valid measure, and in so far as the tests given are tests of the general power of control of the hand by the eye, the study answers the general question: "What relation exists between the ability to draw and mere motor ability of the hand?"

FIG. 1.

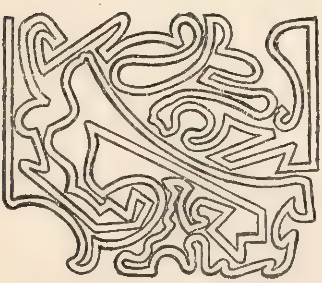
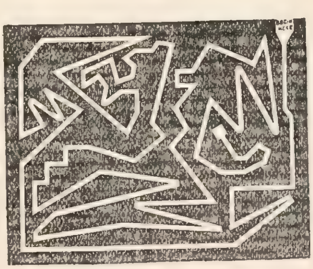


FIG. 2.



The data obtained justify the conclusion that the two abilities are independent of each other, except that students who rank very low in drawing, rank slightly lower than the

average in accuracy of hand movement. This, perhaps, is due to their mental or moral carelessness, rather than to any deficiency in power of motor control.

The measures taken to secure reliable data and the derivation of the results just mentioned, were as follows:

350 students in the first year in the High School were taught drawing by the same teacher (the author of this paper), and at the end of the term each was given a mark on the basis of his capacity and achievement in the work of the course. The marks ran from 50 to 100, the most common mark being 70. These same students were tested with the mazes shown in Figure 1 and Figure 2, all once with each and some twice. They were all given 90 seconds time, all starting and stopping at a signal from the teacher. The mazes from each pupil were scored from 0 to 30, according to the distance covered by each one. This distance was scored from a key, made empirically in the following manner: The average point in the maze reached by a number of individuals in half the time they took to traverse the whole distance was called 15, the point reached in one-quarter the time 7½, etc.

The distance traversed by the pupils for Maze 1 ranged from 9 to 25, the most frequent distance being 14. In Maze 2 the distance traversed ranged from 11 to 25, the most frequent distance being 11.

These mazes were also scored for the number of touches made.

We have thus for each individual a record like the following:

		Maze 1.		Maze 2.	
	Mark.	*Distance.*	*Touches.*	*Distance.*	*Touches.*
John Smith	75	17	4	15	3

In some cases there are two trials with each of the mazes. If now we take all the individuals who did in Maze 1 the

same distance, say 15, we have in the number of touches they made a comparative measure of their accuracy in the test (the distance traversed in the same maze by each pupil being alike for all), and in the mark given by the teacher we have a measure of their ability in drawing.

The relation between accuracy, as shown in the maze test, and ability in drawing, as shown by the teacher's mark, is to be found by finding the co-efficient of correlation for the group.

The facts were tabulated in the following manner:

DISTANCE COVERED 15.

Mark in Drawing:

Touches:	50	55	60	65	70	75	80	85	90	95	100
0					1					1	
1											
2					1		1				
3				1	2						
4					1	1	2				
5					1						
6			1		1						
7							1				
8				1					1		
9			1							1	
10		1	1		1						
11	1										
12											
13						1					
14											
15											
16											
17											
18			1								
19											
	1	1	4	2	8	2	4	0	1	2	0

	Mark below 70.	*Mark 70.*	*Mark above 70.*
Number of cases	8	8	9
Total number touches..........	75	32	41

DISTANCE COVERED 16.

Mark in Drawing.

Touches:	50	55	60	65	70	75	80	85	90	95	100
0											
1										1	
2									1		
3				1							
4			1		2						
5	1				1			1	1		
6			1					1			
7											
8										1	
9								1			
10											
11			1								
12					1						
13											
14											
15											
16											
17											
18											
19	1										
20											
25	1										
	3	0	3	1	4	0	0	3	2	2	

Number of cases, 18.

	Mark below 70.	*Mark 70.*	*Mark above 70.*
Number of cases	7	4	7
Total number touches...........	73	25	36

To save time and gain clearness, groups traversing different distances were combined. The following groups were combined—those traversing distance: 9 and 10, 11 and 12, 13 and 14, etc., and the results were as follows:

FIRST MAZE.

Number of Cases.				Number of Touches.			Average Number of Touches.			General Average.
Distance.	Below 70	70.	Above 70.	Below 70.	70.	Above 70.				
9–10	16	7	11	43	8	25	2.69	1.14	2.27	2.23
11–12	20	9	13	54	23	11	2.70	2.55	.85	2.10
13–14	13	14	10	76	46	10	5.80	3.50	3.57	3.57
15–16	15	12	16	148	57	77	9.90	4.75	4.80	6.80
17–18	6	4	10	16	13	69	2.66	3.25	6.90	4.90
19–20	8	13	17	69	119	71	8.62	9.15	4.18	6.81
21–22	4	3	7	58	39	89	14.50	13.00	12.71	13.28
23–25	9	9	13	175	115	229	19.44	12.77	17.61	16.74
				Sums of Averages.			66.31	49.91	52.82	56.43

The relationship is better seen if we ask in each case not what is the absolute number of touches for bad, mediocre and good students, but what is the proportion of touches in each case to the average number of the whole group doing that distance.

PROPORTION OF TOUCHES IN EACH CASE TO THE AVERAGE OF THE WHOLE GROUP DOING THE SAME DISTANCE

9–10	1.20	.51	1.02
11–12	1.27	1.21	40
13–14	1.62	.92	99
15–16	1.45	.70	.70
17–18	.54	.66	1.48
19–20	1.26	1.34	1.61
21–22	1.08	.98	.95
23–24–25	1.52	.76	1.05
	9.94	7.08	7.20

Dividing by 8, we have 1.255, .885 and .90, the average per cents that the touches of the three classes of students were of the general number of touches.

SECOND MAZE

Distance.	Number of Cases. Below 70.	70.	Above 70.	Sum of Touches. Below 70.	70.	Above 70.	Average Number of Touches.			General Average.
11–12	32	22	21	58	22	19	1.81	1.00	.90	1 32
13–14	7	17	13	6	55	24	.85	3 23	1.84	2.30
15–16	17	8	11	60	25	72	3.53	3.12	6.55	4.36
17–18	9	5	12	67	57	63	7.44	11.40	5.25	7.20
19 to 25	17	8	18	146	58	101	8.60	7.25	5.60	7.09
							22.23	26.00	20.14	22.27

PROPORTION OF TOUCHES IN EACH CASE TO THE AVERAGE NUMBER OF THE WHOLE GROUP DOING THE SAME DISTANCE

11–12	1.45	.76	.68
13–14	.37	1.40	.80
15–16	.81	.71	1.50
17–18	1.03	1.58	.73
19–25	1.21	1.02	.79
	4.87	5.47	4.50

Dividing by 5, we have .974, 1.094 and .90, the average per cents that the touches of the three classes of students were of the general number of touches.

STUDY 2.

The aim of this study was to discover what relationship exists between ability in drawing as measured by the opinion of the teacher as to the pupil's ability in drawing and the ability of these pupils in the other subjects of the High School curriculum as measured by the opinion of the teachers of these subjects.

The data obtained justify the conclusions that ability in drawing is correlated to a greater degree with some of the subjects than with others, but that in no case is the corre-

lation very strong, and that ability in drawing is more of a special ability.

Data for the derivation of the above-mentioned results were as follows:

350 students in the first year of the high school were taught drawing by the same teacher, and at the end of the term each pupil was given a mark on the basis of his capacity and achievement in the work of the course. The marks ran from 50 to 100. Some of these students pursued courses in Botany, Physiology, Zoology, Algebra, Latin, German, French, History and English. At the end of the term the teachers of each of these subjects gave each pupil a mark on the basis of capacity and achievement in the work of the course. These marks ran from 30 to 100.

The marks of each student in drawing and the other departments were tabulated in the following manner:

TERM MARKS.

English.	*Drawing.*										
	50	55	60	65	70	75	80	85	90	95	100
30	1	0	4	3	2	4	2	2	0	0	
35	1	0	0	0	0	1	0	0	0	0	
40	0	0	1	1	1	1	3	1	0	0	
45	0	0	0	1	1	3	1	0	1	1	
50	9	0	7	1	5	6	1	2	2	4	
55	1	0	4	0	3	2	3	1	1	1	
60	2	0	6	9	15	8	3	2	1	2	
65	3	0	3	4	7	5	2	2	0	2	
70	6	0	15	7	12	13	10	6	2	2	
75	6	0	9	3	10	8	8	4	2	2	
80	6	0	8	10	10	6	5	9	3	6	
85	4	0	8	4	11	5	4	2	2	1	
90	5	1	6	2	11	8	10	2	3	4	
95	0	0	0	0	3	2	0	2	3	2	
100				1					1		
	44	1	71	46	91	72	52	35	21	27	
	72.5		73.2	72.5	76.5	72.5	76.8	75.	72.5	77.5	

The figures at the head of the table indicate the mark of the student in drawing, and the figures along the left side indicate the mark of the student in the other subject.

The figure 4 in the first horizontal row of figures under the 60 drawing mark indicates that four students receiving the mark of 60 in drawing received the mark of 30 in English.

The first row of figures under the table indicates the number of students who received the mark of 50, the number the mark of 55, etc.

The second row of figures under the table indicates the mark in English reached by 50 per cent. of the students having the mark 50, 55, 60, etc., in drawing.

The data thus obtained were used to make the diagrams on Plates I. and II.

The figures along the top of Plate I. indicate the scale of marks in drawing and the figures along the left side indicate the scale of marks in the other subject. The figures under each diagram indicate the number of students in each case.

If correlation between ability in drawing and ability in each of the other subjects had been perfect, the line in each diagram should have taken approximately the direction indicated by the dotted line in Diagram 1, Plate I.

The diagrams on Plate III to Plate V were constructed from data obtained in the same manner as that used for constructing the diagrams on Plate I and Plate II.

It is evident from these diagrams that there is a strong correlation between abilities in some of the subjects of the curriculum and very little correlation between others, and that drawing is very much less closely related to the other school subjects than they are among themselves. The ability it involves is clearly not that involved in general academic studies.

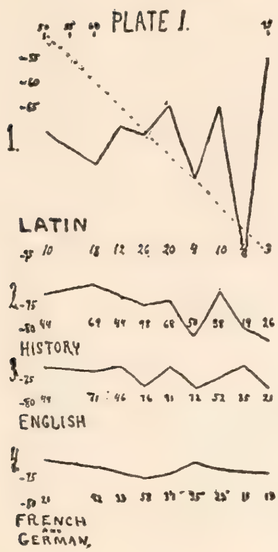


PLATE I.
1.
LATIN
2.
HISTORY
3.
ENGLISH
4.
FRENCH
AND
GERMAN.

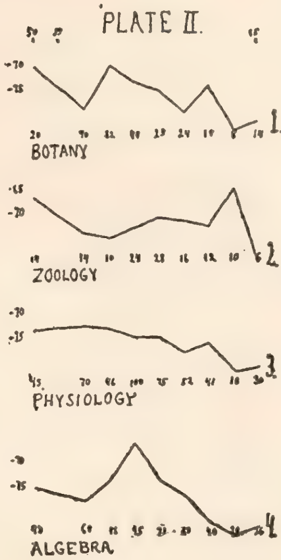


PLATE II.
1.
BOTANY
2.
ZOOLOGY
3.
PHYSIOLOGY
4.
ALGEBRA

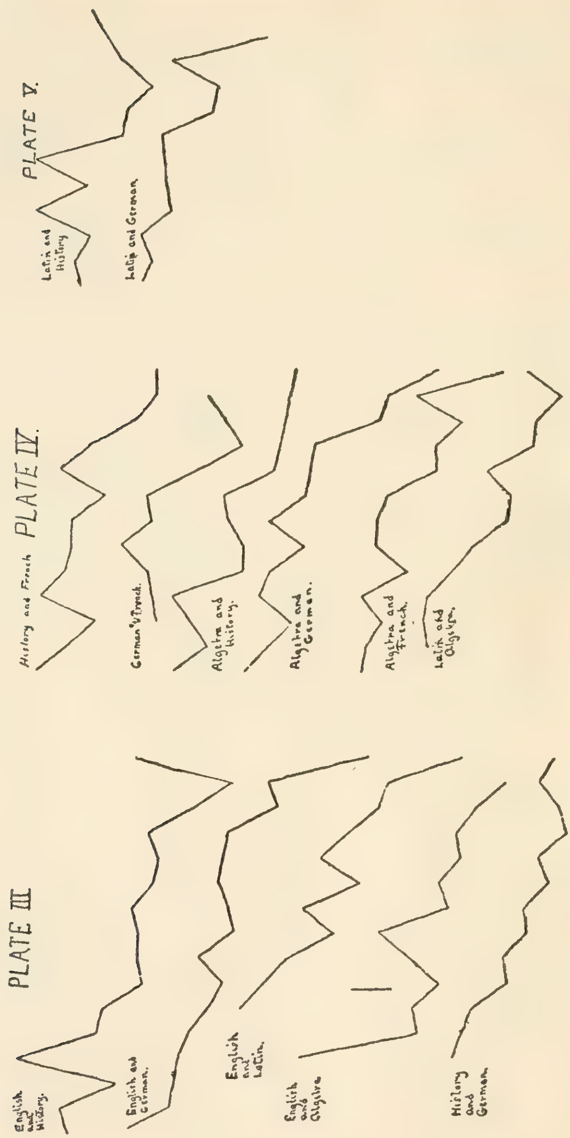


PLATE V.
Latin and History
Latin and German
PLATE IV.
History and French
German & French
Algebra and History
Algebra and German
Algebra and French
Latin and Algebra
PLATE III
English and History
English and German
English and Latin
English and Algebra
History and German